Naval Oceanographic and
Atmospheric Research Laboratory

Technical Note 111
June 1991

DTIC

AD-A243 539

SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

35. ROTA

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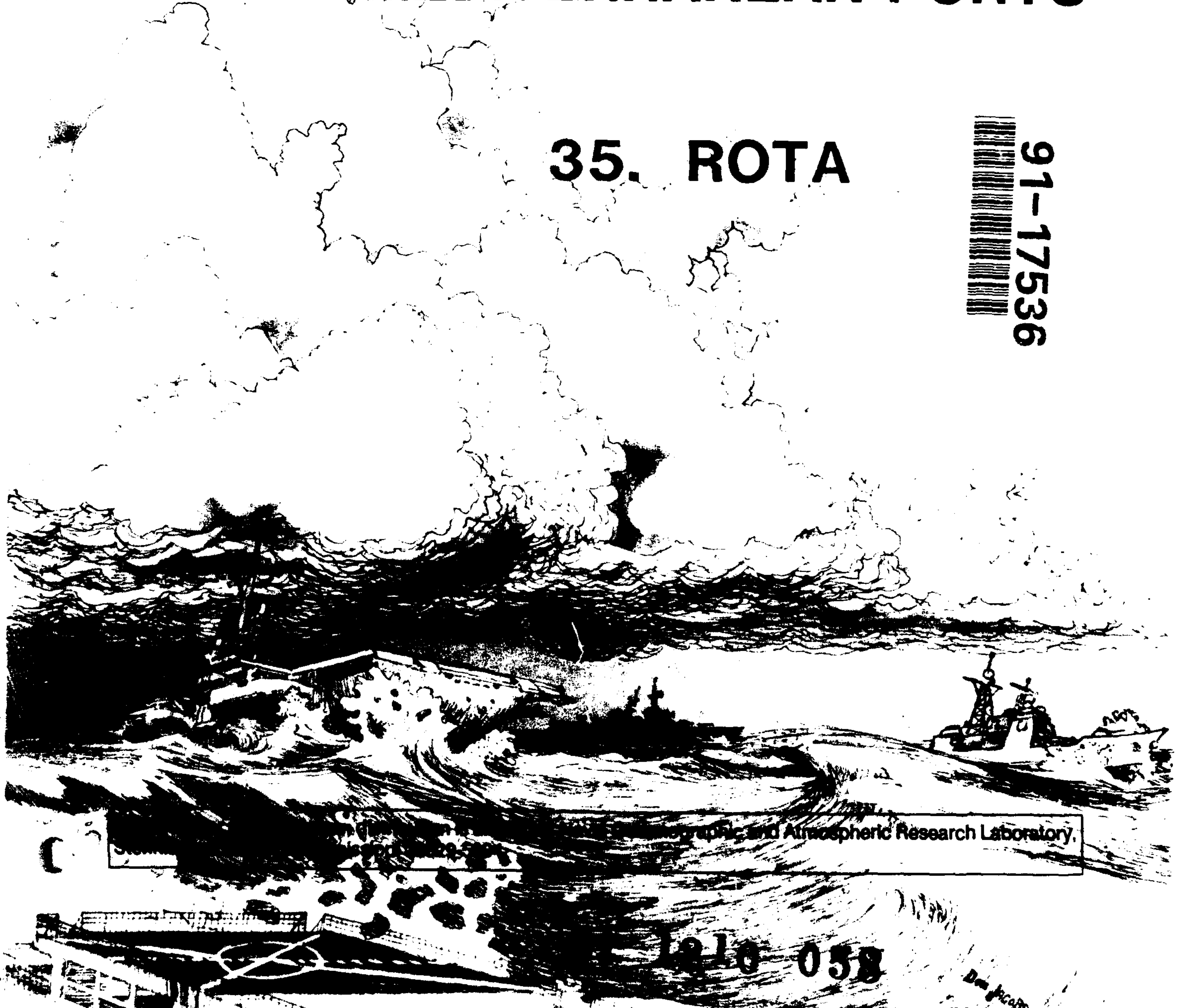

...Oceanographic and Atmospheric Research Laboratory.

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ABSTRACT

This handbook for the port of Rota, Spain, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

ACKNOWLEDGMENTS

The support of the sponsors - Naval Oceanography Command, Stennis Space Center, MS: and Fleet Numerical Oceanography Center, Monterey, CA (Program Element O&M,N) - is gratefully acknowledged.

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FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Atmospheric Directorate, Naval Oceanographic and Atmospheric Laboratory (NOARL), Monterey, to create products for direct application to Fleet Operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to NOARL, Monterey for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review. Computerized versions of these port guides are available for those ports with an asterisk (*). Contact the Atmospheric Directorate, NOARL, Monterey or NOCC Rota for IBM compatable floppy disk copies.

NO.	PORT
*1	GAETA, ITALY
*2	NAPLES, ITALY
*3	CATANIA, ITALY
*4	AUGUSTA BAY, ITALY
*5	CAGLIARI, ITALY
*6	LA MADDALENA, ITALY
7	MARSEILLE, FRANCE
8	TOULON, FRANCE
9	VILLEFRANCHE, FRANCE
10	MALAGA, SPAIN
11	NICE, FRANCE
12	CANNES, FRANCE
13	MONACO
14	ASHDOD, ISRAEL
15	HAIFA, ISRAEL
16	BARCELONA, SPAIN
17	PALMA, SPAIN
18	IBIZA, SPAIN
19	POLLENSA BAY, SPAIN
20	LIVORNO, ITALY
21	LA SPEZIA, ITALY
22	VENICE, ITALY
23	TRIESTE, ITALY
*24	CARTAGENA, SPAIN
*25	VALENCIA, SPAIN
*26	SAN REMO, ITALY
*27	GENOA, ITALY
*28	PORTO TORRES, ITALY
*29	PALERMO, ITALY
*30	MESSINA, ITALY
*31	TAORMINA, ITALY

1991	PORT
*32	TARANTO, ITALY
*33	TANGIER, MOROCCO
*34	BENIDORM, SPAIN
*35	ROTA, SPAIN
*36	LIMASSOL, CYPRUS
*37	LARNACA, CYPRUS
*38	ALEXANDRIA, EGYPT
*39	PORT SAID, EGYPT
40	BIZERTE, TUNISIA
41	TUNIS, TUNISIA
42	SOUSSE, TUNISIA
43	SFAX, TUNISIA
44	SOUDA BAY, CRETE
	VALETTA, MALTA
	PIRAEUS, GREECE

1992	PORT
	KALAMATA, GREECE
	CORFU, GREECE
	KITHIRA, GREECE
	THESSALONIKI, GREECE

DELAYED INDEFINITELY
ALGIERS, ALGERIA
ISKENDERUN, TURKEY
IZMIR, TURKEY
ISTANBUL, TURKEY
ANTALYA, TURKEY
GOLCUK, TURKEY

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

RECORD OF CHANGES

CHANGE NUMBER	DATE OF CHANGE	DATE ENTERED	PAGE NUMBER	ENTERED BY

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

A. A literature search for reference material was performed.
B. Cruise reports were reviewed.
C. Navy personnel with current or previous area experience were interviewed.
D. A preliminary report was developed which included questions on various local conditions in specific harbors.
E. Port/harbor visits were made by NOARLW personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.
F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

A. a brief narrative summary of environmental hazards,
B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,
C. local wind wave conditions, and
D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2 CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both previsit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The

oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The Port of Rota is located southeast of the Gulf of Cadiz on the southwestern coast of Spain about 55 nmi northwest of the Strait of Gibraltar, at approximately 36°37'N6°19'W (Figure 2-1).

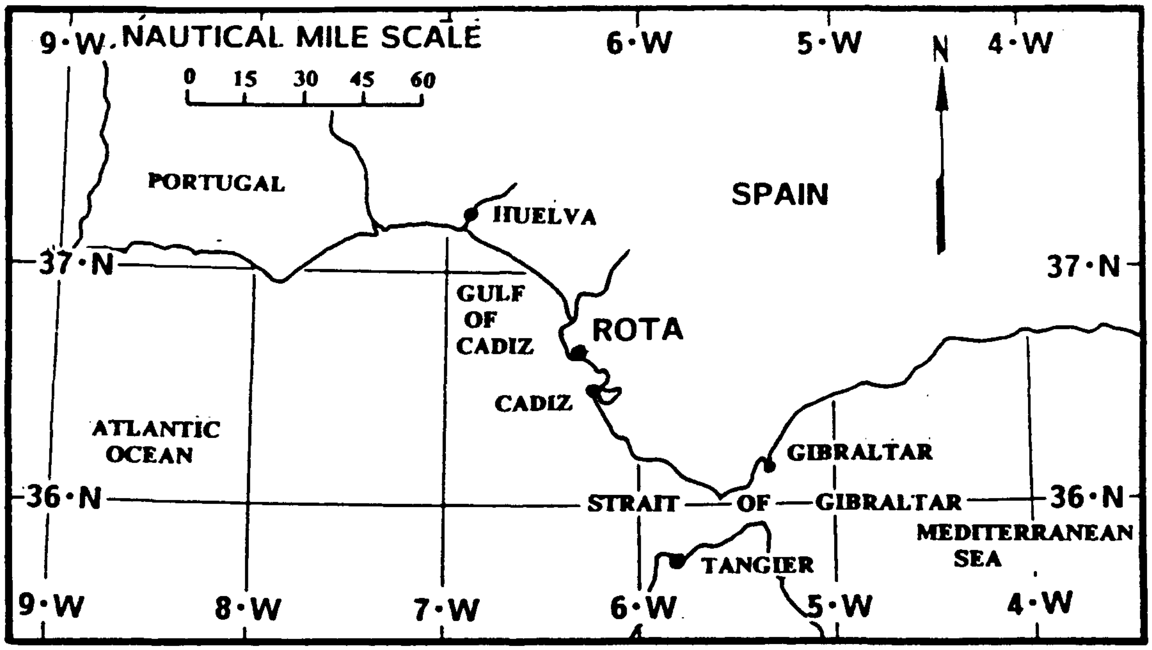

Figure 2-1. Southwestern Spain.

The Port of Rota is situated on the northern shore of the Bay of Cadiz about 6 nmi north-northwest of the City and Port of Cadiz (Figure 2-2).

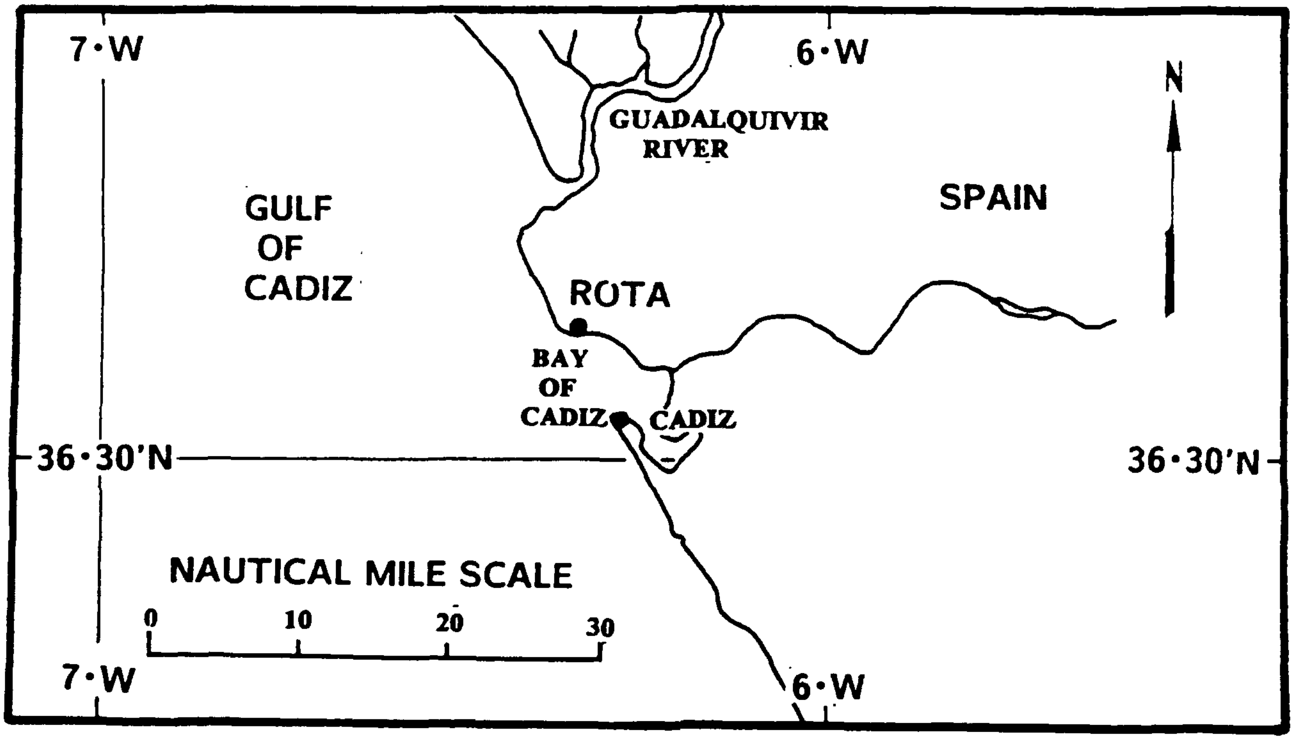

Figure 2-2. Coast of Spain near Rota.

The Port of Rota is a large, deep harbor that can accommodate deep draft vessels even at mean low water. Carriers could be berthed. The enclosed harbor is well protected from wave action from the west, south and east by breakwaters and by the shore to the north (Figure 2-3).

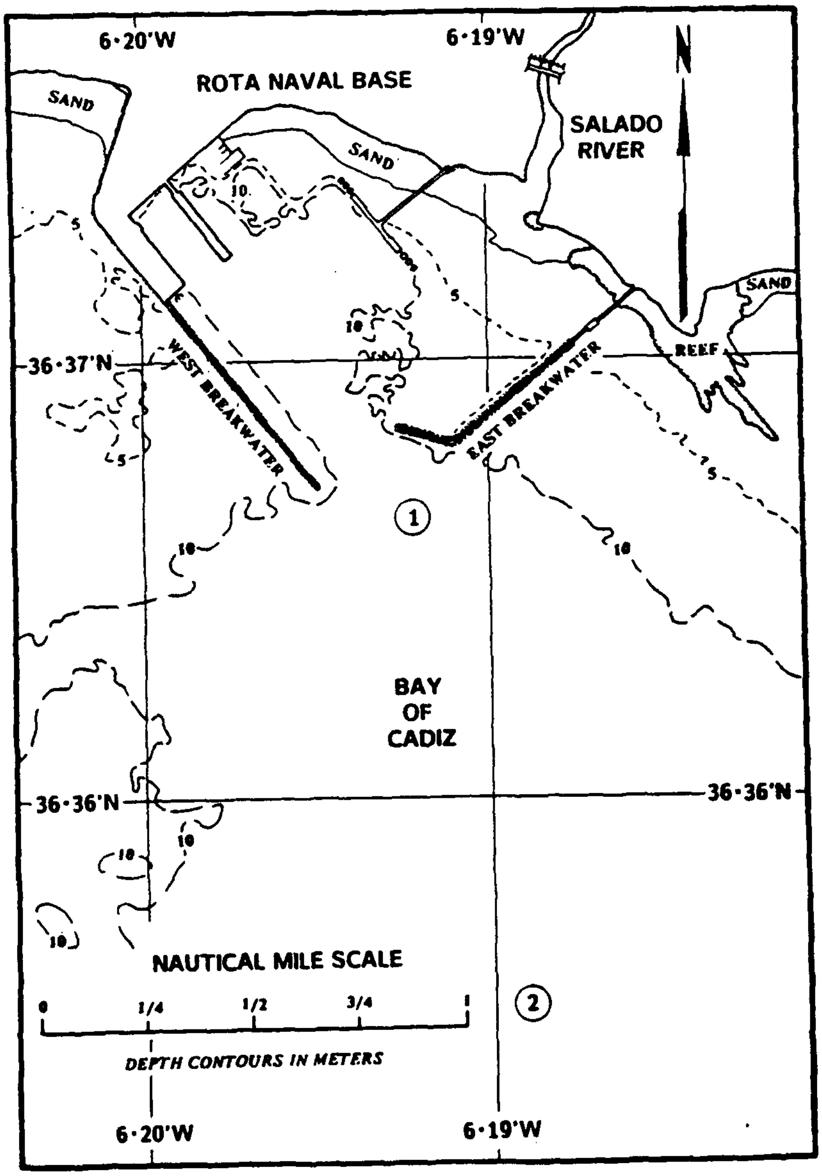

Figure 2.3. Naval Base, Rota, Spain.

However, there is little protection from the wind, especially from the south and west (FICEURLANT, 1987). Ships with large sail areas will, on occasion, have difficulty in berthing or leaving the piers. Easterly winds will keep ships pinned to the main pier berths. One event of record revealed that a tender was forced to remain at berth for 3 days during a strong Levante wind event. Current SOP is for carriers to anchor out. If a carrier were berthed at pier 1 and if only 1 mooring dolphin were available, tug assistance might be required to maintain safe berthing during strong southwest to west winds. Prior established guidance called for one tug on a CV's bow at 20 kts and 3 tugs at 25 kts. Other large sail area ships also require tug assistance at pier 1 during strong westerly winds.

The harbor can house numerous ships and provides ample turning space in the center harbor basin. All vessels except small vessels must use tug assistance when berthing. The limited number of USN tugs restricts berthing action to one ship at a time. Pilotage is compulsory, pilots board just outside the west breakwater.

The average spring tides have a mean range of 9.6 ft (3m). During ebb tides west setting currents may be experienced up to 1.5 knots. Maximum depths are along side the piers. Deep draft vessels such as large oilers are restricted in movement within

the harbor to times near high tide, AO-22 class within 4 hours and AO-143 class within 2 hours of high tide.

A large anchorage area with designated anchorages is located in a general southeastward direction from the breakwater light at the end of the west breakwater. Distance to anchorages varies between 2000 and 7000 yards. A smaller anchorage area is located to the south and southwest of the light at distances of 500 to 750 yards. Anchorages are fully exposed to wind and waves from the west and southwest and may experience up to 10-12 ft (3+m) waves during periods of high winds. Even light to moderate sustained southwesterly winds will produce bothersome chop in the anchorage areas. Small boat operations are normally curtailed when winds exceed 22 kts and/or waves exceed 3 ft (1m). The ratio of anchorage wind to Rota station wind (runway wind reading) is 1.75 to 1, inner harbor ratio is 1.5 to 1. These ratios generally apply for winds from the east-southwest clockwise through northwest (NAVOCEANCOMCENROTA, 1990). The higher winds over the water are taken into consideration when local wind warnings are issued. Contact the U.S. Naval Oceanography Command Center on extension 2625 for weather information.

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Table 2-1. Summary of hazardou

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARI
1. Strong SW'ly Wind - Associated with frontal passages. * Most likely and most intense during winter. * Gale force winds, sea and swell to 12 ft (3m).	1. Advance Warning * A shift of wind di from offshore to o * Falling pressure a clouds approaching west. * Arrival of long pe low swell. * Rota Station issue warnings. Duration * If system approach SW or W, slow movi may persist for 2 days. * If system approach NW, fast moving, p in about 12 hrs, b be followed by oth fronts at 36 to 48 intervals. * Winter pattern of frequent passages quickly establishe following initial frontal passage.

hazardous environmental conditions for the Port of Rota, Spain.

S OF HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT-PRECAUTIONARY/EVASIVE ACTIONS
wind direction ore to onshore. essure and roaching from long period	(1) Anchorages	(a) <u>Anchorage areas are fully exposed to SE'ly winds and fetch limited waves</u>. * Wind stress on large sail area vessels and swing on single anchor may require deployment of a second anchor. * Entry into Harbor not a likely option due to limited tug availability. * Normally sortie not necessary.
on issues area pproaches from ow moving and for 2 to 3	(2) Moored in Harbor	(a) <u>Harbor offers little protection from winds</u>. * Large sail area vessels may be pinned against Pier 1. Tug assistance required for movement off Pier 1. * Some wave energy from Cadiz Bay reaches fuel pier via bridge opening in southern breakwater. * Deep draft vessel movement within Harbor limited to periods near high tide.
pproaches from ving, passes hrs, but may by other 6 to 48 hr ern of ssages is ablished nitial autumn sage.	(3) Small Boat Operations	(a) <u>Small boat operations typically canceled outside Harbor with SW'ly 20 kt or greater winds.</u> * Operate in lee of ships in anchorage. * Beware of different response to waves by varying length vessel.

Tab

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZ
2. Strong SE'ly Wind - Locally known as "Levante". * Strongest and most frequent in summer, but occurs year round. * Gale force winds a couple of times a year, 20 to 30 kt events a couple of times a month during summer. * Wave heights limited to 4 to 6 ft (1-2m) and periods of 3-5 sec by limited fetch length to SE. * Restricted radar and radio ranges.	Advance Warning * Levantes often fol Mistral wind event * High pressure deve over western Mediterranean and pressure over Gulf Cadiz. * Mid-day east to no wind at Rota Stati often precedes Lev one day. * A concentration of and insects are of noted a day ahead arrival of Levante * Strong easterly wi through Strait of Gibraltar. * Daily intensity fo sea breeze cycle. Duration * Strong Levantes ge last for several d * Warm season events longer than cold s events, winter eve frequently last on day.
3. Thunderstorms - Occur with and following frontal passages. * Most likely mid-September to early June. * Strong gusty variable direction winds. * Heavy rain, lightning and low visibility. * Following slow moving fronts activity may persist for 2 to 3 days.	Advance Warning * Approach and pass frontal systems. * Approach of marit polar air from th Atlantic. Duration * During Autumn and thunderstorms may for two to three following frontal passage. * Individual cells typically last le an hour, but new development may overlap to produc several hours of continuous activi

Table 2-1. (Continued)

RS OF AL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT-PRECAUTIONARY/EVASIVE ACTIONS
I ten follow d events. re developing n an and low er Gulf of t to northeast a Station des Levante by tion of bugs are often ahead of Levante winds. erly winds ait of sity follows cycle.	(1) Anchorages	(a) <u>Anchorage areas are fully exposed to SW'ly winds and waves</u>. * Moving into Harbor provides protection from waves but not from wind. * No reported cases of need to sortie to open ocean. * Waves are choppy with multiple wave periods, varying vessel responses make along side and/or well deck operations extra hazardous. * Reduced visibility, heavy rains and fog increases hazards of operations.
	(2) Moored in Harbor	(a) <u>Harbor offers little protection from winds.</u> * Large sail area vessels may require tug assist to stay on Pier 1. * Movement within Harbor generally restricted during strong wind events. * Movement of deep draft vessels from piers limited to times near high tide periods.
ntes generally veral days. events last cold season ter events last only a	(3) Small Boat Operations	(a) <u>Short period seas additional hazard.</u> * Fetch limited to about 6 nmi, seas of 3-5 second periods increase hazards of small boat operations. * Operate in lee of vessels. Operation generally curtailed during moderate to strong Levantes. * Beware returning to anchorage areas after drop-off of wind on/nearshore, over water strong winds may persist all night.
I d passages of tems. maritime rom the north mn and Winter ms may develop three days rontal cells ast less than t new may follow or produce rs of nearly activity.	(1) All Locations/ Situations	(a) <u>Over water thunderstorms generally winter problem.</u> * Occur with and following frontal passage * Activity may persist for 2 to 3 days after slow moving front. * Strong gusty variable direction winds will cause rapid swinging and/or movement of vessels. Doubling lines or second anchor advisable. * Activity is typically intermittent. * Over water most intense late night early morning.

SEASONAL SUMMARY OF HAZARDOUS WEATHER CONDITIONS

WINTER (November through March):

- o Southwesterly winds and waves associated with frontal systems. Winds 30 to 50 kts and waves 10 to 12 ft. Visibility restrictions due to low ceilings and rain preceding and during frontal passage with potential for heavy fog during night following frontal passing.

  Frontal passage may be as frequent as every 36 hours when strong northwesterly flow aloft prevails. Frontal systems approaching from the southwest tend to move slowly and frontal type weather may persist for 2 to 3 days.

- o Near zero visibility in dense fog may last until mid-day following frontal passage.

- o Mean winds are east 7 kts, shifts to westerly winds indicates changing weather pattern, typically frontal in nature.

SPRING (April, May):

- o Hazardous weather rare during spring. Frontal activity decreases in frequency and is significantly weaker. Prevailing wind becomes westerly 7 to 14 kts.

SUMMER (June through September):

- o Hot and dry

- o Southeasterly gusty winds of 18 to 24 kts with gusts of 45 kts associated with Levantes. Winds are strongest during the warmest part of the day. Strong southeasterly flow will persist well into night in the harbor and anchorage areas, long after winds on shore have subsided. Anomalous radar and radio ranges likely.

- o On occasion, fog and low stratus develop after a couple days of strong Levante winds.

- o Low stratus and dense fog associated with a Gulf of Cadiz Eddy. Although rare, may last for several days once established.

AUTUMN (October):

- o Winter-like frontal passages likely during last half of month.

NOTE: For more detailed information on hazardous weather conditions, see Table 2-1 in this section, Hazardous Weather Summary in Section 3 and the Local Area Forecasters Handbook, Rota, Spain.

References

FICEURLANT, 1987: Port Directory for Rota, Spain. Fleet Intelligence Center Europe and Atlantic, Norfolk, VA.

NAVOCEANCOMCENROTA, 1990: United States Navy Local Area Forecaster's Handbook for Naval Station, Rota, Spain. U.S. Naval Oceanography Command Center, Box 31, FPO NY 09540-3200.

Port Visit Information

January 1989. NOARL meteorologists R. Fett and D. Perryman met with Rota Port Commander CDR O'Neill, Port Services Officer LCDR Tuggle and Senior Pilot Ferguson to obtain much of the information included in this port evaluation. NAVOCEANCOMCENROTA was also visited and much useful information obtained.

3. General Information

This section is intended for Fleet meteorologists/oceanographers and staff planners. Section 3.5 includes a general discussion of hazards and Table 3-5 provides summary of vessel locations/situations, potential hazards, effect-precautionary/evasive actions, and advance indicators and other information by season.

3.1 Geographic Location

The Port of Rota is located southeast of the Gulf of Cadiz on the southwestern coast of Spain, about 55 nmi northwest of the Strait of Gibraltar, at approximately 36°37'N 6°19'W (Figure 3-1).

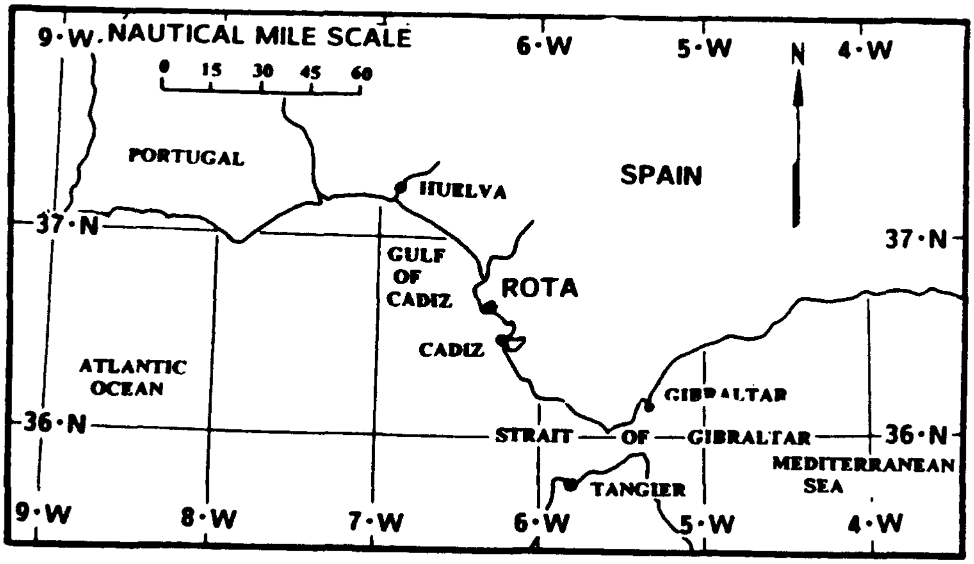

Figure 3-1. Southwestern Spain.

The Port is situated on the northern shore of the Bay of Cadiz about 6 nmi north-northwest of the City and Port of Cadiz (Figure 3-2).

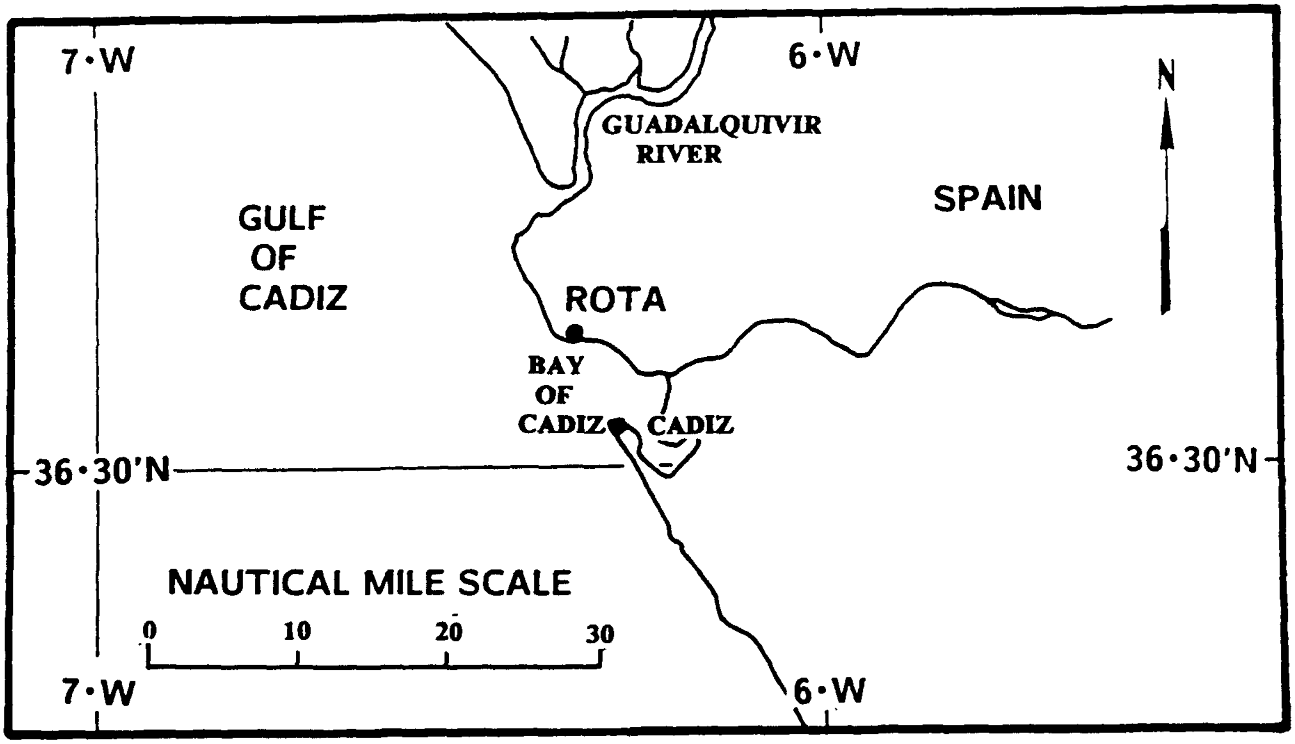

Figure 3-2. Coast of Spain near Rota.

The Port of Rota is a large deep harbor that can accommodate deep draft vessels even at mean low water. Carriers could be berthed at Pier 1 but movement would be restricted to times near high tide, current SOP is for carriers to anchor out. The harbor is well protected from wave action from the west, south and east by breakwaters and by the shore to the north (Figure 3-3).

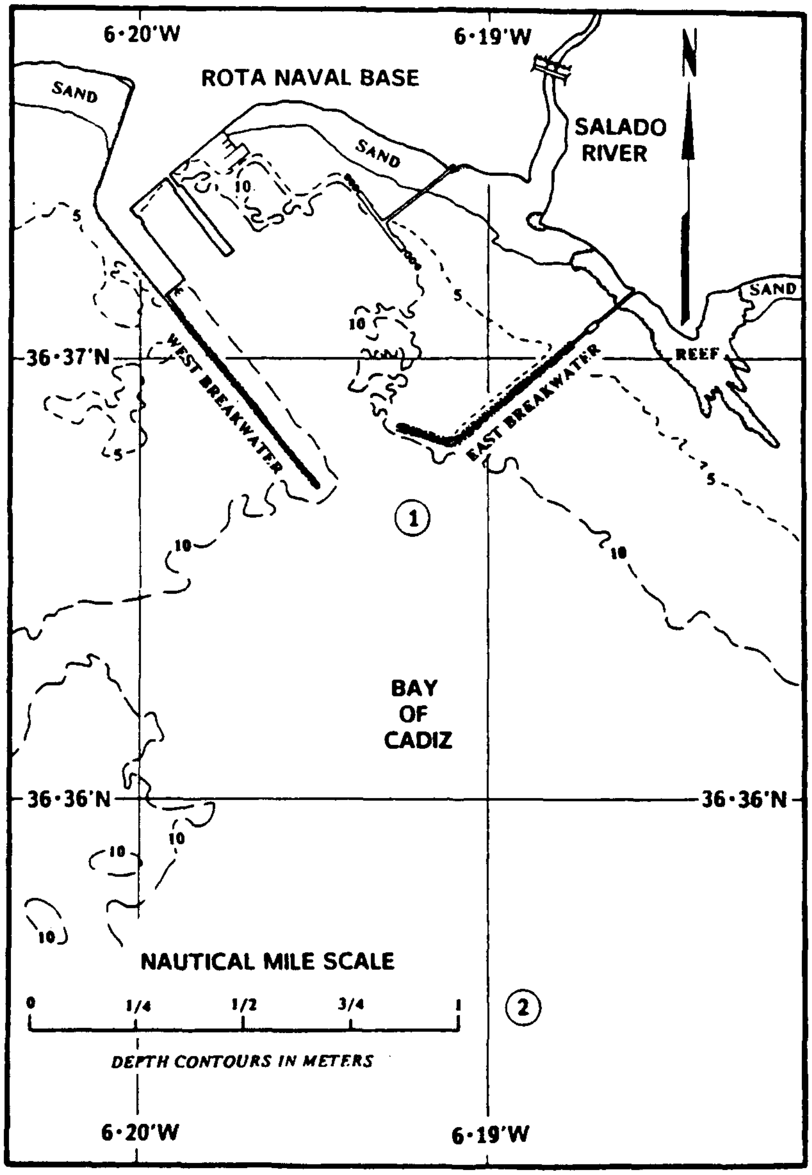

Figure 3-3. Naval Base, Rota, Spain.

However, there is little protection from the wind, especially from the south and west (FICEURLANT, 1987). The harbor entrance is over 300 yards (275m) wide and opens to the south. Approach to the Bay of Cadiz is best from the west and southwest, turning on the harbor range approximately .2 nmi from the breakwater. Minimum depths near turning point are about 46 ft (14m) and decrease to about 36 ft (11m) at entrance. There is no specified channel approaching the harbor entrance.

The harbor can house numerous ships and provides ample turning space in the center harbor basin. All vessels except small vessels must have tug assistance when berthing. The limited number of USN tugs restricts berthing action to one ship at a time. Pilotage is compulsory, pilots board just outside the west breakwater.

A large anchorage area with designated anchorages is located in a general southeastward direction from the breakwater. Distance to anchorages varies between 2000 and 7000 yards (1830 and 6400m). A smaller anchorage area is located to the south and southwest of the light at distances of 500 to 730 yards (457m-667m).

3.2 Qualitative Evaluation of the Port of Rota

The harbor is well protected from wave action but provides little protection from winds, especially those from the south or west. Vessels with large sail areas require tug assistance to be held against pier 1 during strong west wind events. Strong southeast (Levante) winds tend to pin ships to the main pier (pier 1). One recorded incident reports a tender being forced to remain at berth for 3 days during a strong Levante (40 kts).

The anchorages are fully exposed to open ocean waves with only shoaling effects to dampen deep water sea or swell. Wave heights at anchorages run 70 to 90% of deep water wave heights when waves are from the south clockwise through west-northwest (NAVOCEANCOMCEN, 1990).

The strongest winter frontal system which in general approach from the northwest are significantly weakened as they pass over the land area of Portugal to the northwest of Rota. Levante winds which are strongest in summer arrive in the Rota area as southeasterlies. The maximum fetch length to the southwest across the Bay of Cadiz is 6 nmi, therefore sea heights in the Bay are limited to 3 to 4 ft (1+m) in even the strongest Levantes.

3.3 Currents and Tides

The Port Directory for Rota (FICEURLANT, 1987) states that the average tidal range during spring tides is 9.5 ft (3m) with a maximum of 11.5 ft (3.5m). The overall range is stated as 7.1 ft (2m). Tidal currents can be as high as 1.5 kts during ebb tide with a west set.

Note that deep draft vessel harbor entry/departure is limited to times near high tide. Reported minimum alongside depths at low-water are: Pier 1, 42.5 ft (13m) (NAVOCEANCOMCEN, 1990), and Fuel Pier 40 ft (12m) with 36 ft (11m) approach limits (FICEURLANT, 1987).

3.4 Visibility

Prevailing summer time visibility is typical Mediterranean, with afternoon visibility restricted to 3 to 4 nmi in haze. Summer visibility restrictions due to fog may follow Levante events. Two different combinations of factors can result in fog at Rota. One results from the sea breeze advecting warmer moist air over near shore colder upwelled water. The other results from development of a Gulf of Cadiz eddy which can advect fog northward to the Rota area from the coast of Morocco and western Strait of Gibraltar region.

Winter reduced visibilities are associated with frontal weather. Low visibility due to fog occurs during the period of October through March. Visibility of less than one-half nmi occurs in the early morning hours, usually with south to southeast winds. Two to three times a year visibility will stay at one nmi or less for three to four days. See the Rota Local Area Forecaster's Handbook for additional details on visibility.

3.5 Hazardous Conditions

The Port of Rota provides little protection from winds. The breakwaters do provide significant protection from open bay and ocean waves. One exception is waves from the southeast which can come under the bridge on the southeast breakwater and affect ships at Pier 3. Ships with large sail areas will at times, even with tug assistance, have problems berthing or departing due to strong winds. Summer Levante winds are the most bothersome and reach maximum force (30 kts gusting to 50 kts) in the afternoon. The maximum fetch within the Bay of Cadiz is about 6 nmi to the southeast of the anchorage area. Waves of 4 to 6 ft (1-2m) are experienced during strong Levantes.

Anchorage areas are fully exposed to winter season westerly winds and waves. Frequent frontal passages can bring sea and swell of 12 ft (3-4m) and gale force winds. When cyclonic development occurs to the west or southwest of Rota strong

southwesterly winds, high waves and reduced visibility in rain and fog may persist for two to three days.

The limited draft in the harbor approaches to piers restricts movement of deep draft vessels to plus or minus a few hours of high tides. Small boat operations are typically curtailed when winds exceed 22 kts and/or waves exceed 3 ft (1m).

Winds from the southwest clockwise through northwest are significantly stronger at the anchorage and inner harbor locations than at the official Rota wind observation site (runway AN/CMG-29) aerovane (NAVOCEANCOMCEN, 1990). Ratio of over water to over land range from 1.5:1 to 1.9:1.

Extreme temperature events, greater than 90°F in summer and below freezing in winter both occur when the synoptic scale winds result in offshore flow. The funneling effect of the Guadalquivir River Valley (see Figure 3.2) extending north and northeast of Rota is a local topographic influence factor in extreme temperature events.

A seasonal summary of various known environmental hazards that may be encountered in the Port of Rota follows:

A. Winter (November through March)

Hazardous weather and high seas associated with frontal passages are the primary winter season problem. Frontal passages are frequent as indicated by the average 12 days of rain per month. The predominant air mass is maritime polar. The intensity and speed of movement of frontal systems varies in response to the eastern Atlantic ridge configuration and polar front jet stream strength. The "Local Area Forecaster's Handbook for Rota" provides details on winter weather and forecasting. The most prolonged and severe weather generally occurs when a cut-off low develops to the southwest of Rota. This is typically associated with an Omega type blocking pattern.

The average winter wind at the airfield is east at 7 kt. However, severe weather will be associated with westerly winds. Over the water sustained westerly winds of 40 to 50 kts will be experienced during passage of strong frontal systems during all months of winter. The westerly winds associated with frontal passages will push vessels off Pier 1; tug assistance may be required to hold positions. Heavy swell will enter the area when west to southwest winds prevail.

Early morning thunderstorm activity over water will occur during the time between passage of the surface front and that of the 500 mb trough. With slow moving systems thunderstorm activi-

ty may occur for 2 to 3 days running.

January is the coldest month of the year, with a mean daily maximum temperature of 61°F (16°C) and a mean daily minimum of 43°F (6°C). The extreme low temperature of 25°F (-4°C), however, was recorded in December 1970 (NAVOCEANCOMROTA, 1990). Periods of near or below freezing temperatures can be experienced in November through March. These periods of extreme minimum temperatures are associated with outbreaks of polar/arctic air which reaches the Rota area from over Europe. Favorable conditions for extreme minimum temperatures include: 1)north-northeast wind at 500 mb, 2) 500 mb height below 5647m, and 3) clear skies and light northeast surface winds at night. While not a concern on most days at Rota wind chill--the cooling effect of temperature combined with wind--is a factor to be considered on cool, windy days during winter for personnel working in exposed locations. Table 3-1 can be used to determine wind chill for various temperature and wind combinations.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"								
Knots	MPH	Temperature (°F)								
		Equivalent Chill Temperature								
Calm	Calm	40	35	30	25	20	15	10	5	0
3-6	5	35	30	25	20	15	10	5	0	-5
7-10	10	30	20	15	10	5	0	-10	-15	-20
11-15	15	25	15	10	0	-5	-10	-20	-25	-30
16-19	20	20	10	5	0	-10	-15	-25	-30	-35
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55

SPRING (April and May)

Hazardous weather rare during spring. Frontal activity decreases in frequency and intensity. Maximum sustained winds over water likely to be in 30 to 35 kt range.

SUMMER (June through September)

Levante winds are the only hazardous conditions of recurring threat in the Rota area. Locally the winds are southerly and gusty. On average, gale force events will occur a couple of times each year. Weaker events are common a couple of times each month. Levantes typically last for only a day, but strong events have been known to last for eight days. Maximum wind speeds

occur in the afternoons. Levante winds typically drop off at night.

Winds of moderate gale force are the primary threat. Fetch length to the southeast is limited to 6 nmi. Maximum wave heights expected are 4-6 ft (1-2m). Small boat operations are likely to be curtailed. Vessels with large sail areas are likely to be pinned against Pier 1. Levante events are associated with high pressure and strong low level inversions are common. Strong low level wind shear accompanies the inversion and can be a threat to low level flight. Anomalous radar and radio propagation likely. Helicopters may lose radio contact at a few miles range.

AUTUMN (October)

Winter frontal passage pattern usually well established by end of month. Normally, once the first frontal passage is experienced, the winter pattern is in control and the winter frequency of frontal passage is quickly established. Winter type wind, wave, visibility, thunderstorm and precipitation characteristics are also quickly established.

3.6 Harbor Protection

The Harbor is well protected from waves but offers little protection from winds. The anchorage areas are fully exposed to winds but have some protection from waves due to fetch limitations except from the southwest sector.

3.6.1 Wind and Weather

Severe wind and weather of the winter season approach from the western sector. Approaches from the southwest and west are from the open ocean and bring the most severe winter conditions. The anchorages and harbor provide little protection from the frontal related wind and weather of winter. Gale force winds and precipitation occur frequently throughout the winter period. Large sail area ships may need tug assistance to be held against Pier 1.

The primary hazard during summer is the strong winds associated with Levante events. Hot, dry, gusty southeasterly winds of gale force can be expected a couple of times each summer. Wind events approaching gale force will occur several times each season. Severe weather factors are limited to low level inversion/wind shear/turbulence during Levantes and associated flight hazards. Short periods of fog and low stratus may be experienced for a day or two following strong Levantes.

3.6.2 Waves

The harbor is protected from open ocean winter time waves by breakwaters. The anchorages are, howeve:, fully exposed to open ocean waves from the southwest and west. Wave heights of 12 ft (3-4m) can be expected during periods of strong southwesterly winds. The sector from northwest clockwise through south-southeast have limited fetch lengths.

Small boat operations are typically canceled during moderate to strong westerly wind events. Vessels with large sail areas may need tug assistance to maintain safe berthing at Pier 1 when the wind will be moving the vessels off the pier.

The strongest summer Levante southeasterly winds will build waves of 4 to 6 ft (1-2m) in the anchorage area. Wave heights of 3 to 4 ft (1m) are typical during Levantes. The fetch length to the southeast is limited to about 6 nmi. Small boat operations outside the harbor will likely be curtailed during moderate to strong Levantes. Large sail area ships may be pinned to Pier 1 during strong southeasterly winds.

Table 3-2 provides the shallow water wave conditions at the two designated points when the deep water swell enters the area.

Example: Use of Table 3-2.

For a deep water wave condition of 10 feet, 16 seconds, from 210°, the approximate shallow water wave conditions are:

Point 1: 7 feet, 16 seconds, from 200°

Point 2: 10 feet, 16 seconds, from 235°

Table 3-2. Shallow water wave directions and relative height conditions versus deep water period and direction (see Figure 3-3 for location of the points).

FORMAT: Shallow Water Direction
Wave Height Ratio: (Shallow Water/Deep Water)

ROTA POINT 1: Harbor Entrance Depth 36 ft

Period (sec)	6	8	10	12	14	16	18
Deep Water Direction	Shallow Water Direction and Height Ratio						
180°	185° .3	195° .4	210° .4	185° .4	180° .4	185° .4	185° .4
210°	205° .7	200° .6	205° .6	205° .6	205° .7	200° .7	210° .6
240°	225° .5	220° .5	260° .5	260° .5	255° .5	245 .5	265° .5
270°	220° .6	215° .6	215° .6	220° .5	225° .4	220 .4	200° .4
300°	230° .3	230° .3	230° .3	230° .3	220° .3	220° .4	215° .3

ROTA POINT 2: Anchorage Depth 45 ft

Period (sec)	6	8	10	12	14	16	18
Deep Water Direction	Shallow Water Direction and Height Ratio						
180°	195° .4	210° .4	205° .4	210° .5	225° .6	225° .6	225° .6
210°	220° .9	225° .8	230° .8	230° 1.0	230° 1.0	235° 1.0	235° .9
240°	240° .8	245° .7	235° .6	240° .6	245° .6	230° .6	240° .6
270°	265° .8	260° .7	245° .8	255° .6	245° .6	240° .6	260 .6
300°	280° .6	270° .6	260° .5	255° .3	255° .4	250° .4	255° .4

Situation-specific shallow water wave conditions resulting from deep water wave propagation are given in Table 3-2, while

the seasonal climatology of wave conditions in the harbor resulting from the propagation of deep water waves into the harbor are given in Table 3-3. If the actual or forecast deep water wave conditions are known, the expected conditions at the two specified harbor areas can be determined from Table 3-2. The mean duration of the condition, based on the shallow water wave heights, can be obtained from Table 3-3.

Example: Use of Tables 3-2 and 3-3.

The forecast for wave conditions tomorrow (winter case) outside the harbor are:
15 feet, 16 seconds, from 300°

Expected shallow water conditions and duration:

	Point 1	Point 2
Height	6 feet	6 feet
Period	16 seconds	16 seconds
Direction	from 220°	from 250°
Duration	21 hours	30 hours

Interpretation of the information from Tables 3-2 and 3-3 provides guidance on the local wave conditions expected tomorrow at the specified area points. The duration values are mean values for the specified height range and season. Knowledge of the current synoptic pattern and forecast/expected duration should be used when available.

Possible applications to small boat operations are selection of the mother ships anchorage point, and/or areas of small boat work. The condition duration information provides insight as to how long the current condition can be expected to persist before a decrease in height to below 3.3 ft or 6.6 can be expect-

ed. The local wave direction information can be of use in selecting anchorage configuration and related small boat operations, including tending activities.

Table 3-3. Shallow water climatology as determined from deep water wave propagation. Percent occurrence, average duration or persistence, and wave period of maximum energy for wave height ranges of greater than 3.3 ft (1 m) and greater than 6.6 ft (2 m) by climatological season.

ROTA POINT 1:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	14	5	5	14
Average Duration (hr)	21	23	25	28
Period Max Energy(sec)	11	12	11	11
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	2	1	1	2
Average Duration (hr)	20	20	18	15
Period Max Energy(sec)	14	14	15	16
PORT SAID POINT 2:	WINTER	SPRING	SUMMER	AUTUMN
>3.3 ft (1 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	29	16	16	32
Average Duration (hr)	30	65	34	36
Period Max Energy(sec)	11	11	9	9
>6.6 ft (2 m)	NOV-APR	MAY	JUN-SEP	OCT
Occurrence (%)	5	3	2	4
Average Duration (hr)	20	21	24	16
Period Max Energy(sec)	12-15	12-15	12-15	12-14

Deep water wave climatology off Rota includes cases of south to south-southwest long period (≥15 sec) high (20-24 ft) waves

during August through April. The shallow water wave model indicates that energy from these waves reach the anchorage/ entrance areas as 13 to 16 ft, long period, swell. The model also indicates a bimodal distribution of wave energy versus wave period with a peak in 3 to 6 ft waves at 9-11 seconds and a peak in 9 to 15 ft waves at 15-16 seconds. If these conditions occur simultaneously all alongside, nesting or well deck operations involving varying length vessels will be additionally hazardous. Other potential hazards related to these wave conditions include grounding of longer length vessels in the marginal water depths due to large vessel response to the long period wave action.

Local wind wave conditions are provided in Table 3-4. Because of the close proximity of the anchorage and entrance to the harbor, and similar exposure to wind, only one set of wind wave data are provided.

Table 3-4 is based on certain pre-existing and concurrent conditions. First, the time to reach the fetch limited height assumes an initial flat ocean. A second condition is that the wind waves do not "feel" the bottom, that is their length does not reach the critical 1/2 depth value at which point wave speed starts to decrease and height and steepness increase. (See Appendix A for additional information on wave parameters.) Because the Bay of Cadiz is relatively shallow, wind waves of 3 to 4 second periods (30 to 55 ft length) may as a result of

bottom effects have heights greater than the 3 to 4 ft indicated in Table 3-4. The heights of 4 to 6 ft reported in the Forecaster's Handbook are in reasonable agreement with pure wind wave generated heights of 3 to 4 ft that are increased by shoaling (feeling the bottom) effects.

Table 3-4. Rota. Local wind waves for fetch limited conditions at Points 1 and 2 (based on JONSWAP model).

Points 1 and 2.

Format: height (feet)/period (seconds)
time (hours) to reach fetch limited height

Fetch Length (n mi) \ Local Wind Speed (kt)	18	24	30	36	42
3	<2 ft	<2 ft	2/3 1	2/3 1	2-3/3 1
6	<2 ft	2/3 1-2	3-3/4 1-2	3-4/3-4 1-2	4/4 1

Example: Small boat wave forecasts for Points 1 & 2 (based on the assumption that swell is not a limiting condition).

Forecast for Tomorrow:

Time	Wind (Forecast)	Waves (Table 3-4)
prior to 0800 LST	light & variable	< 2 ft
0800 to 1300	SE 22-26 kt	2 ft at 3 sec by 0900
1300 to 1800	SE 34-38 kt	*4-6 ft at 3-4 sec by 1400
1800 to 2100	SE decreasing to less than 24 kt	2-3 ft at 3 sec by 1900

*Due to bottom effect in shoal areas, heights of 4 to 6 ft should be forecast for areas inside 30-35 m depth contour.

Interpretation: Assuming that the limiting factor is waves greater than 3 feet, small boat operations will be curtailed by 1400 and remain so until after 1800.

Combined wave heights are computed by finding the square root of the sum of the squares of the wind wave and swell

heights. For example, if the wind waves were 3 ft and the swell 8 ft the combined height would be about 8.5 ft.

$$\sqrt{3^2 + 8^2} = \sqrt{9 + 64} = \sqrt{73} \approx 8.5$$

Note that the increased height is relatively small. Even if the two wave types were of equal height the combined heights are only 1.4 times the equal height. In cases where one or the other heights are twice that of the other, the combined height will only increase over the larger of the two by 1.12 times (10 ft swell and 5 ft wind wave combined results in 11.2 ft height). This computation applies to deep water areas and does not take into consideration increased wave heights due to bottom effects.

3.6.3 Wave Data Uses and Considerations

Local wind waves build up quite rapidly and also decrease rapidly when winds subside. The period and, therefore, length of wind waves is generally short relative to the period and length of waves propagated into the harbor (see Appendix A). The shorter period and length result in wind waves being characterized by choppy conditions. When wind waves are superimposed on deep water waves propagated into shallow water, the waves can become quite complex and confused. Under such conditions, when more than one source of waves is influencing a location, tending or joint operations can be hazardous even if the individual wave

train heights are not significantly high. Vessels of various lengths may respond with different motions to the diverse wave lengths present. The information on wave periods, provided in the previous tables, should be considered when forecasts are made for joint operations of various length vessels.

3.7 Protective and Mitigating Measures

Positioning anywhere inside the breakwaters provides protection from wave action. The harbor offers minimal protection from the major wind related problems. Exposure to wind and waves is essentially equal throughout the anchorage area.

3.7.1 Scheduling

During summer the diurnal variation of the land/sea breeze may be a factor in scheduling. The typical daily regime is the onset of sea breeze by late morning with maximum onshore winds of 10 to 15 kts by mid afternoon and dropping off after sunset occurs. Levante wind speeds follow a similar diurnal pattern, however, over water strong events are likely to persist through the night.

During winter the synoptic variations are of greater importance in scheduling. Frontal activity is quite frequent with about 40% of the days experiencing some form of unsettled weather.

about 40% of the days experiencing some form of unsettled weather.

3.8 Indicators of Hazardous Weather Conditions

The summer and winter seasons each have characteristic hazardous weather events. The Levante southeasterly winds create several, at least unpleasant, events each season while winter frontal passages occur frequently from late October through March.

Levante wind events first develop over the western Mediterranean. An essential synoptic feature is higher pressure over the western Mediterranean/Eastern Spain region, and lower pressure in the Gulf of Cadiz. The Levante evolution is influenced by a venturi effect through the Strait of Gibraltar and establishment of a lee side thermal trough extending from the west coast of Morocco northward across the Gulf of Cadiz to Portugal. The Strait will generally experience funneled easterly winds from 20 to 55 kts prior to the onset of southeasterlies of 15 to 35 kt in the Rota area. The Rota Forecasters Handbook contains a number of Levante related forecast rules.

Local indicators which may provide advance warning of the onset of a Levante include: 1) a late morning to afternoon offshore wind, vice normal onshore sea breeze, at the airfield.

This wind anomaly often precedes a Levante by one day. 2) Local mariners use "Levante Bugs" as a warning. A day before the Levante reaches Rota, a combination of bugs and insects ahead of the strong easterly winds may be observed.

During winter the approach of frontal systems may be indicated by arrival of long period swell. Fast moving fronts approaching from the northwest may be preceded by westerly swell. Slower moving fronts associated with cyclonic development to the southwest of Rota are likely to be preceded by southwesterly swell. Cyclone development of this type may also be reflected by increased speeds of the prevailing easterly offshore winds.

Any reversal of the prevailing summer onshore or winter offshore wind patterns are indicative of synoptic scale changes and likely foretell of approaching unsettled weather.

3.9 Summary of Problems, Actions and Indicators

Table 3-5 is intended to provide easy-to-use seasonal references for meteorologists on ships using the Port of Rota. Table 2-1 (section 2) summarizes Table 3-5 and is intended primarily for use by ship captains.

Table 3-5. Potential problem

VESSEL LOCATION/ SITUATION	POTENTIAL HAZARD	EFFECT - PREC
1. Anchorages Commences mid to late October most intense winter, rare after May.	(a) SW'ly wind and waves - Frontal systems. Gale force winds, 12 ft (3-4m) waves, rain and low visibility. Choppy wave conditions.	(a) Worst conditi Wind and wave second anchor along side or ous length (w hazardous. S side in lee o anchor draggi
Year around most intense and frequent in summer during afternoons.	(b) SE'ly wind and waves - Levante Gale force events 2 or 3 a year. Winds of 20-30 kts couple of times a month in summer. Maximum wave periods of 4 to 6 ft (1-2m) at 3 to 5 sec. periods. Reduced visibility in Mediterranean type haze. Anomalous radar/radio ranges.	(b) Unpleasant su boat operatio Low level tur ated with tem ous to flight around 50 kts 900m). Wind night/early m radio ranges.
Mid-September to early June. Maximum intensity early morning.	(c) Thunderstorms. Post-frontal. Gusty variable winds, choppy waves, heavy rain.	(c) Gusty variabl tion. Rough small boats. bility and li canceling fli ing wind dire hazards. Pre and anchoring

ential problem situations at Port of Rota, Spain - All Seasons

FECT - PRECAUTIONARY/EVASIVE ACTION	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
Worst conditions when winds from southwest. Wind and waves *not* extreme but may require second anchor. Choppy confused waves make along side or well-deck operations of various length (wave period response) vessels hazardous. Small boats should come along side in lee of large vessels. No reports of anchor dragging.	A. Frontal passages occur most often and are most intense during winter. Winter pattern quickly established following initial autumn passage. The jet stream intensity, large scale circulation pattern and variations in the Azore High position/strength determine direction of approach. Fronts from the NW are fast moving and lose energy over land areas to the NW of Rota. Fronts *from the W are more intense and slower moving.* Fronts associated with lows to the SW of Rota result in prolonged frontal weather (2-3 days). Daytime wind speeds over the water are higher than those reported for the station by a factor of about 1.6:1. High winds over the water areas are likely to continue throughout the night, while those over land typically drop off after sunset. Satellite imagery is considered the best source of information. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. See Rota Area Forecasters Handbook for comprehensive forecast rules.
Unpleasant summer time conditions. Small boat operations may have to be curtailed. Low level turbulence and wind shear associated with temperature inversion are hazardous to flight operations. Maximum winds around 50 kts between 1500-3000 ft (450-900m). Wind shear strongest over land at night/early morning. Limited radar and radio ranges.	B. Levantes occur when there is higher pressure over the western Mediterranean and lower pressure over the Gulf of Cadiz. During the normal sea breeze season a mid-day east to northeast wind at the Station (disruption of normal on-shore sea breeze) often precedes a Levante by one day. Local mariners use the appearance of "Levante Bugs" which are concentrated ahead of the easterly winds moving out of the Mediterranean the day before onset at Rota as an indicator of an approaching Levante. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. Wind speeds over the water are higher than those reported on the Station by a factor of about 1.6:1. High winds may continue throughout the night over the water areas. See the Rota Area Forecasters Handbook for comprehensive forecast rules.
Gusty variable winds and heavy precipitation. Rough wave conditions may curtail small boats. Winds, turbulence, low visibility and lightning hazards may require canceling flight operations. Rapidly changing wind directions can cause ship swinging hazards. Precautions in ship positioning and anchoring are pertinent.	C. Over water thunderstorms can be associated with frontal passages, but more frequently occur in the air mass between the surface front and the trailing 500 mb trough line. Slow moving systems may result in 2 to 3 days of activity. Maximum intensity over water typically occurs in early morning. Satellite imagery is the best short term source of information. Upper air 500 mb indicators include: Below normal heights, 5637 m (winter), 5647 m (spring), 5875 m (summer) and 5637 m (autumn); wind from about 260 degrees at 50 kts or more and similar direction winds of 100 kts or more at the jet stream level. Warnings and Conditions for the harbor and anchorage areas are issued/set by Rota Station authorities. See the Rota Area Forecasters Handbook for comprehensive forecast rules.

Table 3-5. (Continued)

VESSEL LOCATION/ SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVA
2. Moored in Harbor Commences mid to late October most intense winter, rare after May.	(a) SW'ly wind and waves - Frontal systems. Gale force winds, 4-5 ft(1-1.5m) waves in the harbor and 6-8 ft (2-2.5m) waves in the anchorage, rain and low visibility. Choppy wave conditions.	a. During gale force winds vessel sail area likely to require tug as stay on Pier 1. Extra lines will Pier 1 for all vessels. Choppy wa develop quickly with onset of high draft vessel movement from piers 1 high tide periods due to shallower
Year around most intense and frequent in summer during afternoons.	(b) SE'ly wind and waves - Levante Gale force events 2 or 3 a year. Winds of 20-30 kts couple of times a month in summer. Maximum wave periods of 4 to 6 ft (1-2m) at 3 to 5 sec. periods. Reduced visibility in Mediterranean type haze. Anomalous radar/radio ranges.	b. Large sail area vessels may be 1 for duration of wind event. Som will reach the Harbor through the Vessels at fuel pier will experien due to bridge opening in south bre draft vessel movement from piers 1 high tide periods due to shallower
Mid-September to early June. Maximum intensity early morning.	(c) Thunderstorms. Post-frontal. Gusty variable winds, choppy waves, heavy rain.	c. Strong gusty variable directi to cause variable ship movements Movement from fuel pier by deep d limited to periods near high tide

Table 3-5. (Continued)

/E	:CT - PRECAUTIONARY/EVASIVE ACTION	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
itł tar rec coı nd: tec prı	:ing gale force winds vessels with large :ea likely to require tug assistance to ı Pier 1. Extra lines will be required at for all vessels. Choppy wave conditions › quickly with onset of high winds. Deep 'essel movement from piers limited to near .de periods due to shallower approaches.	A. Frontal passages occur most often and are most intense during winter. Winter pattern quickly established following initial autumn passage. The jet stream intensity, large scale circulation pattern and variations in the Azore High position/strength determine direction of approach. Fronts from the NW are fast moving and lose energy over land areas to the NW of Rota. Fronts from the W are more intense and slower moving. Fronts associated with lows to the SW of Rota result in prolonged frontal weather (2-3 days). Daytime wind speeds over the water are higher than those reported for the station by a factor of about 1.6:1. High winds over the water areas are likely to continue throughout the night, while those over land typically drop off after sunset. Satellite imagery is considered the best source of information. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. See Rota Area Forecasters Handbook for comprehensive forecast rules.
nne ave rar hic ate tec pr	ge sail area vessels may be pinned to Pier uration of wind event. Some wave energy ach the Harbor through the entrance. at fuel pier will experience higher waves bridge opening in south breakwater. Deep essel movement from piers limited to near de periods due to shallower approaches.	B. Levantes occur when there is higher pressure over the western Mediterranean and lower pressure over the Gulf of Cadiz. During the normal sea breeze season a mid-day east to northeast wind at the Station (disruption of normal on-shore sea breeze) often precedes a Levante by one day. Local mariners use the appearance of "Levante Bugs" which are concentrated ahead of the easterly winds moving out of the Mediterranean the day before onset at Rota as an indicator of an approaching Levante. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. Wind speeds over the water are higher than those reported on the Station by a factor of about 1.6:1. High winds may continue throughout the night over the water areas. See the Rota Area Forecasters Handbook for comprehensive forecast rules.
wi be t t	rong gusty variable direction winds likely se variable ship movements at berths. nt from fuel pier by deep draft tankers d to periods near high tide.	C. Over water thunderstorms can be associated with frontal passages, but more frequently occur in the air mass between the surface front and the trailing 500 mb trough line. Slow moving systems may result in 2 to 3 days of activity. Maximum intensity over water typically occurs in early morning. Satellite imagery is the best short term source of information. Upper air 500 mb indicators include: Below normal heights, 5637 m (winter), 5647 m (spring), 5875 m (summer) and 5637 m (autumn); wind from about 260 degrees at 50 kts or more and similar direction winds of 100 kts or more at the jet stream level. Warnings and Conditions for the harbor and anchorage areas are issued/set by Rota Station authorities. See the Rota Area Forecasters Handbook for comprehensive forecast rules.

Table 3-5. (Continued)

VESSEL LOCATION/ SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE A
3. Small Boat Operations Commences mid to late October most intense winter, rare after May.	(a) SW'ly wind and waves - Frontal systems. Gale force winds, 4-5 ft(1-1.5m) waves in the harbor and 6-8 ft (2-2.5m) waves in the anchorage, rain and low visibility. Choppy wave conditions.	a. Operations generally canceled for an areas and curtailed in harbor. Boats sho ate to lee side of ships. Beware of var responses by different length vessels.
Year around most intense and frequent in summer during afternoons.	(b) SE'ly wind and waves - Levante Gale force events 2 or 3 a year. Winds of 20-30 kts couple of times a month in summer. Maximum wave periods of 4 to 6 ft (1-2m) at 3 to 5 sec. periods. Reduced visibility in Mediterranean type haze. Anomalous radar/radio ranges.	b. Operations curtailed for anchorages; should operate in lee of ships. Early m and after sunset periods of lower winds/ Wave periods are short, ships should exp limited response, small boats maximum re
Mid-September to early June. Maximum intensity early morning.	(c) Thunderstorms. Post-frontal. Gusty variable winds, choppy waves, heavy rain.	c. Sudden onset of strong gusty winds able directions create unexpected hazar uninformed/unprepared. Station hazardo weather/wind warnings/conditions should closely monitored.

Table 3-5. (Continued)

ECT - PRECAUTIONARY/EVASIVE ACTION	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
erations generally canceled for anchorage and curtailed in harbor. Boats should oper- lee side of ships. Beware of varying ses by different length vessels.	A. Frontal passages occur most often and are most intense during winter. Winter pattern quickly established following initial autumn passage. The jet stream intensity, large scale circulation pattern and variations in the Azore High position/strength determine direction of approach. Fronts from the NW are fast moving and lose energy over land areas to the NW of Rota. Fronts from the W are more intense and slower moving. Fronts associated with lows to the SW of Rota result in prolonged frontal weather (2-3 days). Daytime wind speeds over the water are higher than those reported for the station by a factor of about 1.6:1. High winds over the water areas are likely to continue throughout the night, while those over land typically drop off after sunset. Satellite imagery is considered the best source of information. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. See Rota Area Forecasters Handbook for comprehensive forecast rules.
erations curtailed for anchorages; boats operate in lee of ships. Early morning ter sunset periods of lower winds/waves. eriods are short, ships should experience d response, small boats maximum response.	B. Levantes occur when there is higher pressure over the western Mediterranean and lower pressure over the Gulf of Cadiz. During the normal sea breeze season a mid-day east to northeast wind at the Station (disruption of normal on-shore sea breeze) often precedes a Levante by one day. Local mariners use the appearance of "Levante Bugs" which are concentrated ahead of the easterly winds moving out of the Mediterranean the day before onset at Rota as an indicator of an approaching Levante. Small Craft Warnings and Gale/Storm Conditions applicable to harbor and anchorage areas are issued/set by Rota Station authorities. Wind speeds over the water are higher than those reported on the Station by a factor of about 1.6:1. High winds may continue throughout the night over the water areas. See the Rota Area Forecasters Handbook for comprehensive forecast rules.
dden onset of strong gusty winds and vari- irections create unexpected hazards for the rmed/unprepared. Station hazardous :/wind warnings/conditions should be r monitored.	C. Over water thunderstorms can be associated with frontal passages, but more frequently occur in the air mass between the surface front and the trailing 500 mb trough line. Slow moving systems may result in 2 to 3 days of activity. Maximum intensity over water typically occurs in early morning. Satellite imagery is the best short term source of information. Upper air 500 mb indicators include: Below normal heights, 5637 m (winter), 5647 m (spring), 5875 m (summer) and 5637 m (autumn); wind from about 260 degrees at 50 kts or more and similar direction winds of 100 kts or more at the jet stream level. Warnings and Conditions for the harbor and anchorage areas are issued/set by Rota Station authorities. See the Rota Area Forecasters Handbook for comprehensive forecast rules.

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Port Visit Information

January 1989. NOARL meteorologists R. Fett and D. Perryman met with Rota Port Commander CDR O'Neill, Port Services Officer LCDR Tuggle and Senior Pilot Ferguson to obtain much of the information included in this port evaluation. NAVOCEANCOMCENROTA was also visited and much useful information obtained.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and

the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN-BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea

surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{max} = \frac{2.476}{v} \qquad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end

the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \tag{1.2}$$

Where v is wind speed in knots and $\bar{T}$ is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41\ \bar{T}^2 \tag{1.3}$$

Where $\bar{L}$ is average wave length in feet and $\bar{T}$ is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67\text{"L"} \tag{1.4}$$

where "L" = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves)

period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)	Sig Wave (H1/3 Period/Height (sec) (ft)	Wave Length (ft)[1,2] Developing/Fully /Arisen L X (.5) /L X (.67)
10	28 / 4	4 / 2	41 / 55
15	55 / 6	6 / 4	92 / 123
20	110 / 8	8 / 8	164 / 220
25	160 / 11	9 / 12	208 / 278
30	210 / 13	11 / 16	310 / 415
35	310 / 15	13 / 22	433 / 580
40	410 / 17	15 / 30	576 / 772

NOTES:

1 Depth throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.

2 For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell there wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

A.4 Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.

2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.

3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

<u>Format:</u> height (feet)/period (seconds)
duration required (hours)

Fetch Length (n mi) \ Wind Speed (kt)	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7[1] 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

[1] 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

<u>WIND FORECAST OR CONDITION</u>

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

<u>SEA FORECAST OR CONDITION</u>

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in

wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are

considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

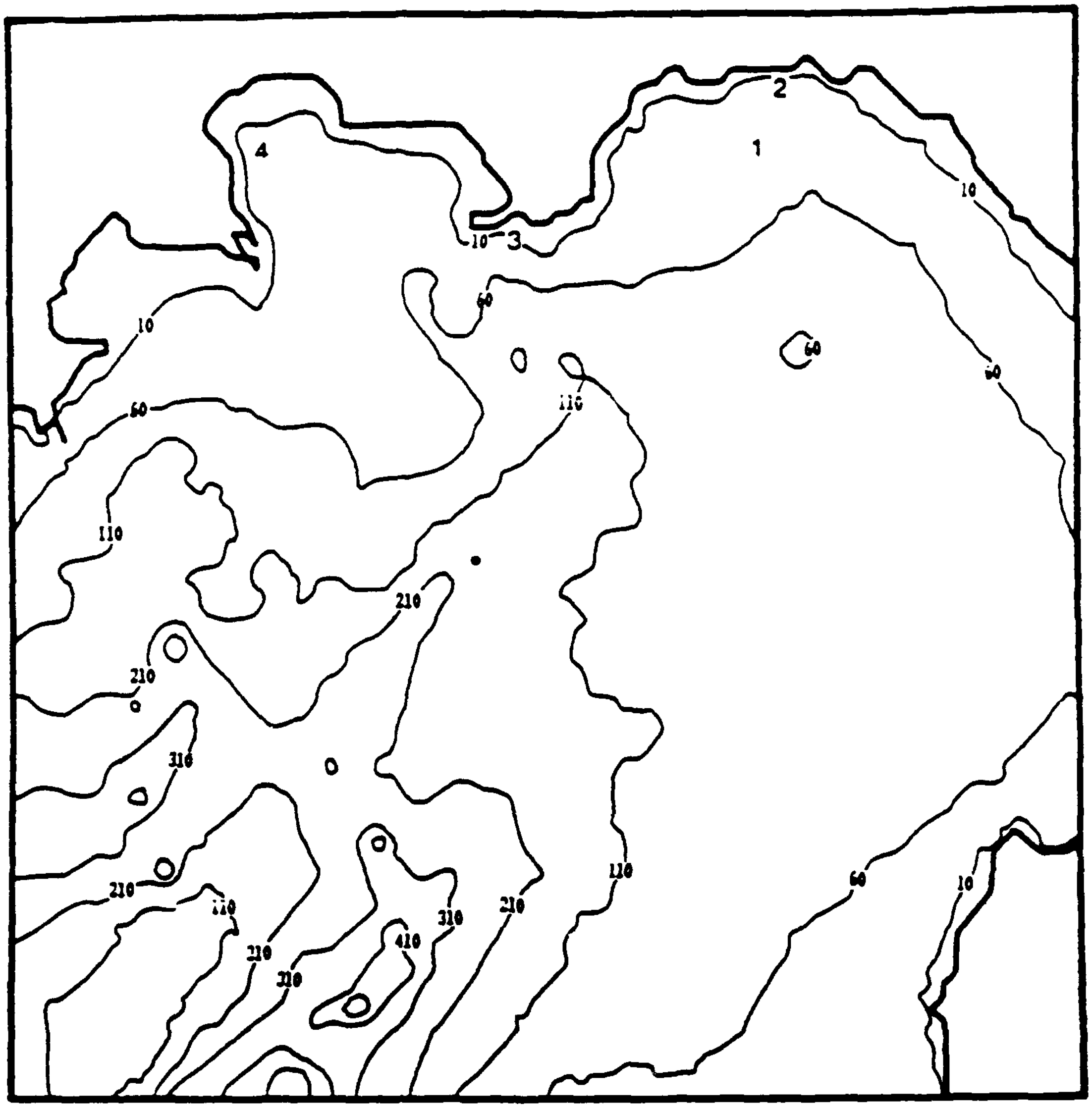

Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathom contour. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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REPORT DOCUMENTATION PAGE

Form Approved
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1. Agency Use Only *(Leave blank).*

2. Report Date. June 1991

3. Report Type and Dates Covered. Final

4. Title and Subtitle.
Severe Weather Guide - Mediterranean Ports - 35. Rota

5. Funding Numbers.
Program Element No. O&M,N
Project No. --
Task No. --
Accession No. DN656794

6. Author(s).
R.E. Englebretson and R.D. Gilmore (SAIC)
D.C. Perryman (NOARL)

7. Performing Organization Name(s) and Address(es).
Science Applications International Corporation (SAIC)
205 Montecito Ave., Monterey, CA 93940

Naval Oceanographic and Atmospheric Research Laboratory,
Atmospheric Directorate, Monterey, CA 93943-5006

8. Performing Organization Report Number.
NOARL Technical Note 111

9. Sponsoring/Monitoring Agency Name(s) and Address(es).
Naval Oceanography Command
Stennis Space Center, MS 39529-5000

10. Sponsoring/Monitoring Agency Report Number.
NOARL Technical Note 111

11. Supplementary Notes.

12a. Distribution/Availability Statement.
Approved for public release; distribution is unlimited.

12b. Distribution Code.

13. Abstract *(Maximum 200 words).*

This handbook for the port of Rota, one in a series of severe weather guides for Mediterranean ports, provides decision-making guidance for ship captains whose vessels are threatened by actual or forecast strong winds, high seas, restricted visibility or thunderstorms in the port vicinity. Causes and effects of such hazardous conditions are discussed. Precautionary or evasive actions are suggested for various vessel situations. The handbook is organized in four sections for ready reference: general guidance on handbook content and use; a quick-look captain's summary; a more detailed review of general information on environmental conditions; and an appendix that provides oceanographic information.

14. Subject Terms.
Storm haven
Rota port
Mediterranean meteorology
Mediterranean oceanography

15. Number of Pages. 71

16. Price Code.

17. Security Classification of Report.	18. Security Classification of This Page.	19. Security Classification of Abstract.	20. Limitation of Abstract.
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	Same as report